Preferential use of Nearshore Kelp Habitats by Juvenile Salmon and Forage Fish

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Abstract
This study was conducted to quantify, for the first time, some basic parameters of juvenile salmon and forage fish use of kelp bed habitats. Findings include:

(1) Juvenile salmon and surf smelt appear to preferentially use kelp bed habitats over unvegetated habitats.
(2) Juvenile salmon appear to prefer the middle of the kelp surface canopy while surf smelt show no habitat use partitioning within the kelp bed.
(3) While prevalent in the nearshore, juvenile sand lance show no preference for kelp over unvegetated habitats.
(4) Juvenile salmon prefer shallow waters, but distance from shore and creek mouth do not appear to be factors for selecting habitats.
(5) Water depth, distance from shore, and distance from creek mouth are not selecting factors for juvenile surf smelt.
(6) Sand lance appear to select for deeper water.

Together, these results indicate that juvenile salmon, surf smelt, and sand lance exhibit complex habitat partitioning within the nearshore. Further defining and understanding these habitat preferences is critical for future wise management of these species and the nearshore habitats that support them.

Introduction
The nearshore marine environment is a unique zone, with consistently higher species diversity, density, and production, than deeper water marine habitats. The nearshore also acts as a base for critical components of the broader marine ecosystem. Juvenile salmon, a commercially and culturally important resource for the west coast, and forage fish, which form the basis of a number of critical food webs, including surf smelt (*Hypomesus pretiosus*) sand lance, *Ammodytes hexapterus*, and herring (*Clupea harengus pallasi*) depend on this nearshore zone for feeding and migration (Fechhelm, et al. 1999; Meyer 1996; Miller et al. 1980; Moulten and Penttila 2000; Penttila 1995; Penttila 2002;). Kelp beds, one of the most diverse of nearshore environments, are a dominant feature of temperate nearshore systems, and are a major feature of shorelines of coastal Washington (Duggins et al 1990, 1989; Shaffer 2000; VanWagenen 1996). These shorelines are also migratory corridors for three federally-listed salmon species Puget Sound Chinook (*Oncorhynchus tshawytscha*) , Hood Canal Summer Chum (*O. keta*), and Bull Trout *Salvelinus confluentus*) as they migrate from inland to coastal waters. All these salmonid species depend on nearshore marine environment for juvenile rearing before migrating offshore to deeper adult habitats (Miller et al. 1980; Roni and Weitcamp 1996; Simenstad et al 1979; Simenstad et al. 1981;Simenstad et al 1988.).

The role of kelp habitats and in particular their contribution to the secondary production of marine systems, has been studied to some degree (Carr 1989; Duggins et al. 1989; 1990; Gaines and Roughgarten 1987; Holbrook et al. 1990; Shaffer et al 1995). Unfortunately, none of these studies have specifically addressed the role of kelp habitats in salmon or forage fish life history. Juvenile salmon and forage fish, which are strongly nearshore and surface oriented during their juvenile stage (Birtwell and Kruzynski 1989; Robards et al 1988), are known locally to be strongly associated with kelp beds along the Strait of Juan de Fuca. Kelp bed use has never been quantified. The purpose of this study is to, for the first time:

(1) Document kelp bed use by juvenile salmon and forage fish.
(2) Define if preferential use of kelp beds is occurring, and if so, identify potential reasons for observed preferences.
(3) Determine if correlations exist between use of kelp beds and nearshore physical features, including distance from shore and creek mouths.

Methods and Materials
Five sites along the Strait of Juan de Fuca were sampled from June through August 2001. Sites were selected for proximity to mouths of creeks of that are of similar size and support important Strait salmonid stocks (Lower Elwha Tribe,.WDFW unpublished data) (Figure 1). Each site consisted of a paired kelp and no-kelp area. Three permanent snorkeling transects were established in each kelp bed to assess inner, middle, and outer areas of each kelp bed. One permanent no-kelp transect was also established at each site. No-kelp transects were in immediate proximity to kelp beds,

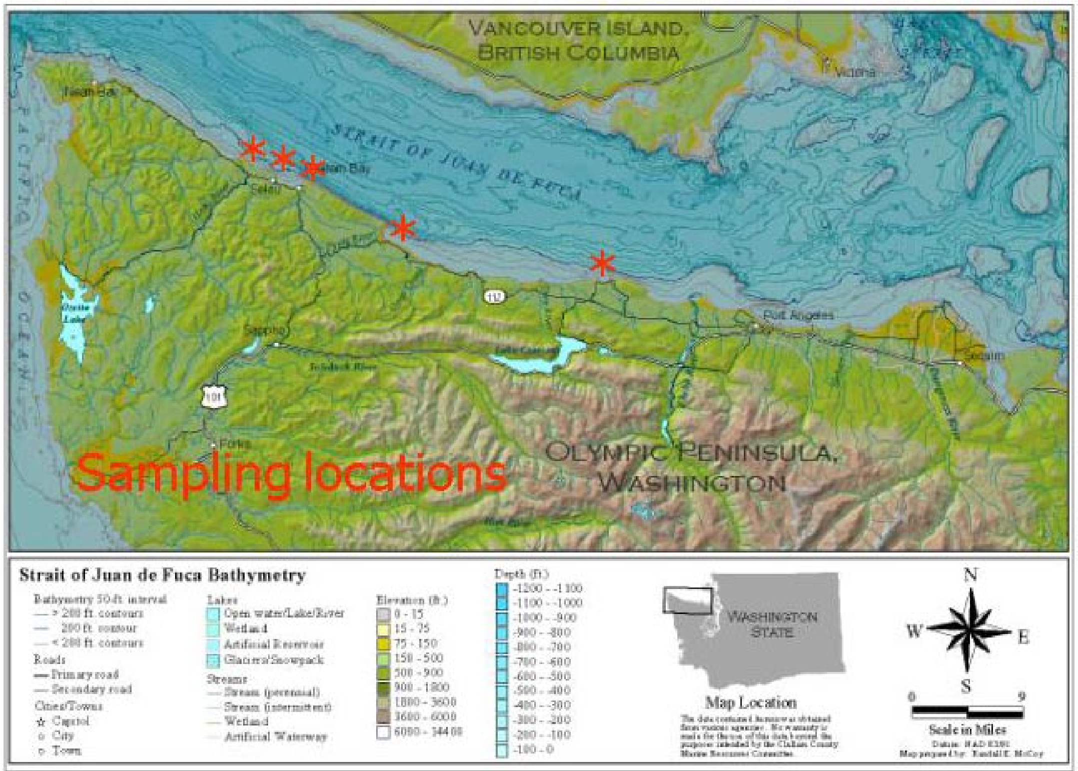

Figure 1. Sampling sites for juvenile salmonid use of kelp beds study, Clallam County 2001. Map created by Randall McCoy, Lower Elwha Klallam Tribe.

and shared the same orientation, depth, and distance from shore. Transect locations were defined by selecting prominent features along the shoreline that were visible from each of the transects and also distinguishable on aerial photos and USGS 7.5 minute quadrangle maps. Lengths of each transect were estimated by pacing off distance parallel shoreline, and confirmed by measurements of aerial photographs in conjunction with USGS 7.5 minute quadrangle maps. Water depth along each transect was determined using boat based SONAR and converted to MLLW. Each kelp/no-kelp area was within 1000 meters of a creek mouth and in water 0-20 feet deep.

For each site, the inner kelp transect was located on the shallow edge, and parallel to, the shoreward edge of the kelp bed. The middle kelp bed transect extended in a straight line across the kelp bed from its inner to outer edge. The outer kelp bed transect covered the outer, deeper, edge of the kelp bed that bordered the main basin of the Strait. No-kelp transects were established along the same depth contour and immediately adjacent to the paired kelp bed, and parallel to the shoreline.

Kelp beds and no-kelp areas were sampled by snorkeling permanent transects. Visibility was a minimum of 15 feet for sampling. Swimmers snorkeled each established transect and noted all juvenile and adult salmon and forage fish observed within three meters of the transect. Fish were identified to major grouping (salmon/ sand lance/ smelt), and kelp type, estimated fish depth, and water depth were recorded for each fish observation. At least two observations on kelp type and water depth were recorded for each transect, regardless of fish presence. All four transects within a site were sampled within two hours. Kelp and no-kelp beds were sampled once a month from June thru August 2001. All five sites were sampled within a two-day time period.

Fish observations were converted to densities (number of fish, both total and by species, per total square feet of transect), determined to be non-normal, and therefore log transformed. For kelp: no-kelp density comparisons, 15 kelp data points (one for each month per site) were randomly selected for statistical comparison with paired no-kelp data. One and two way paired ANOVAs were conducted to determine differences in fish variances in kelp and no-kelp habitats, and preferences, if any, within kelp habitats by each species. Correlations were conducted to determine relationships between individual fish observations and depth, and distance from shore. Correlations were also calculated for total surf smelt, sand lance, and salmon density in kelp habitat and proximity of creek mouths.

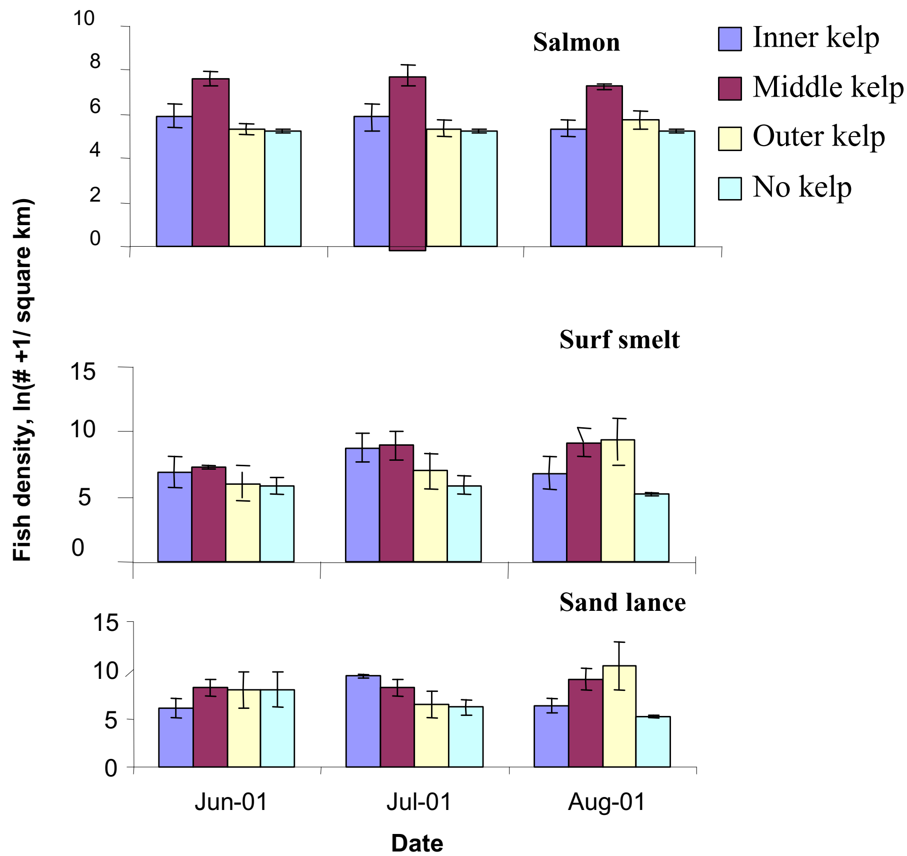

Figure 2. Juvenile salmon and forage fish densities (with SE) in kelp beds of the Strait of Juan de Fuca.

To confirm fish presence and identification, two to three beach seines were conducted at each creek mouth within one hour of snorkeling surveys. Standard seining protocols used as described in Puget Sound Water Quality Action Team (1996). Juvenile salmon and forage fish were counted and preserved in 10% buffered formalin for subsequent stomach analysis. In the lab, fish were identified to species, measured, and stomach contents identified to major order. Percent occurrence by weight and abundance were calculated for each prey species and predator.

Results

Snorkeling surveys

Square area sampled, average depth, and dominant kelp type of each kelp transect are summarized in Table 1. All kelp beds were mixed bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis integrifolia*) with *Egregia menziesii* and *Alaria* spp. along the inner margin. Fish densities varied consistently with site (Table 2 and 3). With all months combined, Salt Creek and Sekiu had highest number of juvenile salmonids and surf smelt for all months sampled, followed by Hoko, Pillar Point, and Clallam Bay. Salt Creek and Sekiu also had highest sand lance densities, followed by Pillar Point, Clallam Bay, and Hoko. When sites were combined, juvenile salmon and surf smelt densities were significantly higher in kelp than non-kelp habitats ($F=4.20$, $F_{crit\ 1,28\ (2)\ 0.05}=4.19$; $P<0.05$ and $F=6.62$ $P<0.05$ respectively). Fish density within each transect is summarized in Table 2. Within kelp beds, salmon density proved significantly higher in middle than outer or inner kelp beds ($F=25.24$; $F_{crit\ 0.05\ (2)\ 3,\ 48}= 3.42$; $P<.001$) for all months sampled. Inner and outer kelp bed densities were not significantly different (Figure 2). Juvenile salmonid presence was significantly negatively correlated to water depth with significantly more fish were found in shallower water;
($R=-0.173$; $R_{crit\ 0.05\ (2)\ 130}=0.170$; $P=0.05$). Fish presence was not significantly correlated to either distance to shore or creek mouth ($R=-0.05$; $R_{crit\ 0.05\ (2)\ 5}=0.755$; $P>0.50$).

Table 1. Areas and average depth (corrected to MLLW, square feet and feet respectively and dominant kelp type of each transect. For kelp type, E=*Egregia menziesii*; N=*Nereocystis luetkeana*; M= *Macrocystis integrifolia*; and A=*Alaria* spp.

Site	Inner Kelp				Middle kelp				Outer kelp				No kelp		
	Area	Depth Ave	- sd	Kelp type	Area -	Depth Ave	- sd	Kelp type	Area	Depth Ave	- sd	Kelp type	Area	Depth Ave	- sd
Clallam Bay	877	3.2	2.4	E,A,M	75	7.6	0.8	M	877	11.9	4.0	M	735	16.0	9.9
Salt Creek	540	2.8	2.1	E,A,N	75	10.4	0.0	N,M	540	19.7	3.9	N,M	540	18.7	8.7
Pillar Pt	573	2.0	1.4	E	75	9.9	2.2	N	573	13.3	3.5	N	400	10.5	2.7
Hoko	500	7.0	2.0	E,A,N	40	10.4	2.1	N	500	8.7	5.3	N	462.5	20.7	0.0
Sekiu	650	3.1	2.1	E	75	7.5	3.7	N,M	650	9.2	3.8	M,N	463.8	7.1	3.0
Total	3140				340				3139.73				2601.3		
Average	628				68				627.95				520.26		
SD	150				15.65				149.59				129.90		

Surf smelt densities were not significantly different within kelp beds. Surf smelt densities were not correlated with distance from creek mouth (R=0.29; $R_{crit\ 0.05\ (2)\ 5}$=0.755) and showed no significant relationship with water depth (R=0.138; $R_{crit\ 0.05\ (2)\ 130}$=0.170).

Sand lance densities were not significantly different between kelp and no-kelp habitats, nor were there significant differences in sand lance densities within kelp beds sampled (Figure 2). Sand lance abundance was highly correlated to water depth (R=0.29; $R_{crit\ 0.05\ (2)\ 130}$=0.170 , $p<0.001$) as well as significantly negatively correlated with distance from creek mouth (R=-0.866; $R_{crit\ 0.05\ (2)\ 5}$=0.755).

Total numbers of sand lance, surf smelt, and juvenile salmon did not change significantly by month. In general, forage fish densities increased over the three month period, while salmon numbers decreased (Figure 2).

Seining

A total of 35 seines were conducted over the sampling period. A total of 246 juvenile and adult surf smelt and 52 juvenile salmon were caught in seines. No sand lance were caught in any of the beach seines. Six juvenile salmon were Chinook, one was a chum, and the remaining 45 were coho. Average length of juvenile coho varied with site and time (Figure 3). All Chinook were collected at Hoko and Clallam Bay. Surf smelt were collected in beach seines only in August at Clallam Bay and Salt Creek sites, with average lengths of 154 and 92.4 mm, respectively.

Stomach content analysis. Average fullness for salmon stomachs was 50%. All surf smelt stomachs were empty. Gammarid amphipods and juvenile sand lance were the dominant prey of juvenile salmon collected by both weight and abundance. Mysids, tanaids, and terrestrial insects and arachnids were also found in much lower proportions (Tables 3 and 4).

Table 2. Average habitat depth observed while snorkeling (in feet) and fish density (ln) by site, date, transect, and species.

			Water depth (feet)		Density (ln)					
					Salmon		Surf smelt		Sand lance	
Site	Date	Kelp Transect	Ave	SD	Ave	SD	Ave	SD	Ave	SD
Clallam River	May	Inner	10.00	5.00	0.60	1.03	0.00	0.00	3.08	2.66
Sekiu	May	Inner	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt Creek	May	Inner	6.67	2.89	6.91	0.00	1.54	0.00	6.91	0.00
Clallam River	Jun	Inner	8.00	3.46	0.00	0.00	1.14	1.98	3.08	17.32
Hoko	Jun	Inner	5.00	0.00	1.39	0.00	0.00	0.00	0.00	0.00
Sekiu	Jun	Inner	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pysht	Jun	Inner	6.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00
Salt Creek	Jun	Inner	4.11	1.36	0.51	0.63	2.96	1.85	0.00	43.62
Clallam River	Jul	Inner	7.00	0.00	0.00	0.48	1.63	2.30	3.59	0.48
Hoko	Jul	Inner	10.00	0.00	0.00	0.00	0.00	0.00	4.62	0.00
Sekiu	Jul	Inner	10.00	0.00	1.52	2.78	3.51	1.57	1.97	2.78
Pysht	Jul	Inner	8.67	2.16	0.00	1.66	1.78	1.67	1.49	1.66
Salt Creek	Jul	Inner	8.67	5.89	0.18	0.45	3.66	1.99	0.77	1.88
Clallam River	Aug	Inner	5.00	0.00	0.00	0.00	0.00	0.00	3.26	0.00
Hoko	Aug	Inner	8.00	2.00	0.83	0.23	1.90	0.00	0.00	0.00
Pysht	Aug	Inner	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt Creek	Aug	Inner	5.00	0.00	0.00	0.00	3.26	0.00	0.00	0.00
Sekiu	Aug	Inner	10.00	0.00	0.00	0.00	0.00	0.00	3.26	0.00
Salt Creek	May	Middle	10.00	0.00	0.00	0.00	0.00	0.00	6.91	0.00
Clallam River	Jun	Middle	7.00	3.00	0.60	2.66	58.33	0.00	0.00	2.66
Hoko	Jul	Middle	20.00	0.00	0.00	0.00	3.93	0.00	0.00	0.00
Sekiu	Jul	Middle	20.00	0.00	1.01	2.27	2.62	2.27	2.62	2.27
Clallam River	Aug	Middle	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pysht	Aug	Middle	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt Creek	Aug	Middle	20.00	0.00	0.00	0.39	4.39	0.39	4.39	0.39
Sekiu	Aug	Middle	22.50	3.54	0.00	2.30	1.97	2.78	1.63	2.30
Clallam River	May	Outer	10.00	7.07	0.00	0.81	0.00	0.00	3.93	0.81
Sekiu	May	Outer	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt Creek	May	Outer	10.00	0.00	0.00	0.00	0.00	0.00	4.62	0.00
Hoko	Jun	Outer	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sekiu	Jun	Outer	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pysht	Jun	Outer	20.00	0.00	0.35	0.00	0.00	0.00	6.91	0.00
Salt Creek	Jun	Outer	18.33	2.89	0.23	3.99	1.54	2.66	2.30	3.99
Clallam River	Jul	Outer	20.00	0.00	0.00	0.00	2.40	0.00	0.00	0.00
Hoko	Jul	Outer	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sekiu	Jul	Outer	15.00	0.00	0.00	0.00	0.00	0.00	6.91	0.00
Pysht	Jul	Outer	7.50	3.54	0.00	0.00	0.00	0.00	0.00	0.00
Salt Creek	Jul	Outer	16.71	4.35	0.35	0.46	4.25	1.99	0.00	132.29
Clallam River	Aug	Outer	25.00	7.07	0.00	0.00	3.16	1.08	0.00	0.00
Hoko	Aug	Outer	10.00	0.00	0.00	0.00	100.00	0.00	10.00	0.00

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Table 2 *continued*

Site	Date	Kelp Transect	Water depth (feet)		Density (ln*)					
					Salmon		Surf smelt		Sand lance	
			Ave	SD	Ave	SD	Ave	SD	Ave	SD
Pysht	Aug	Outer	10.71	1.89	0.10	2.24	0.00	0.00	1.78	2.24
Salt Creek	Aug	Outer	12.50	4.63	0.43	0.64	3.58	1.58	4.98	6.08
Sekiu	Aug	Outer	25.00	0.00	0.17	0.35	2.30	4.61	2.61	1.77
Clallam River	May	No Kelp	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt Creek	May	No Kelp	10.00	0.00	0.69	0.00	4.62	0.00	6.91	0.00
Clallam River	Jun	No Kelp	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hoko	Jun	No Kelp	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sekiu	Jun	No Kelp	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pysht	Jun	No Kelp	15.00	7.07	0.00	0.00	0.00	45.96	3.45	4.89
Salt Creek	Jun	No Kelp	13.00	8.19	2.30	3.99	1.60	1.38	2.30	3.99
Clallam River	Jul	No Kelp	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sekiu	Jul	No Kelp	10.00	0.00	0.00	0.00	0.00	0.00	4.62	0.00
Pysht	Jul	No Kelp	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt Creek	Jul	No Kelp	17.50	10.61	0.00	0.00	1.63	2.30	3.45	4.89
Clallam River	Aug	No Kelp	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hoko	Aug	No Kelp	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pysht	Aug	No Kelp	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt Creek	Aug	No Kelp	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pysht	May	No Kelp	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*ln = natural log (base 2)

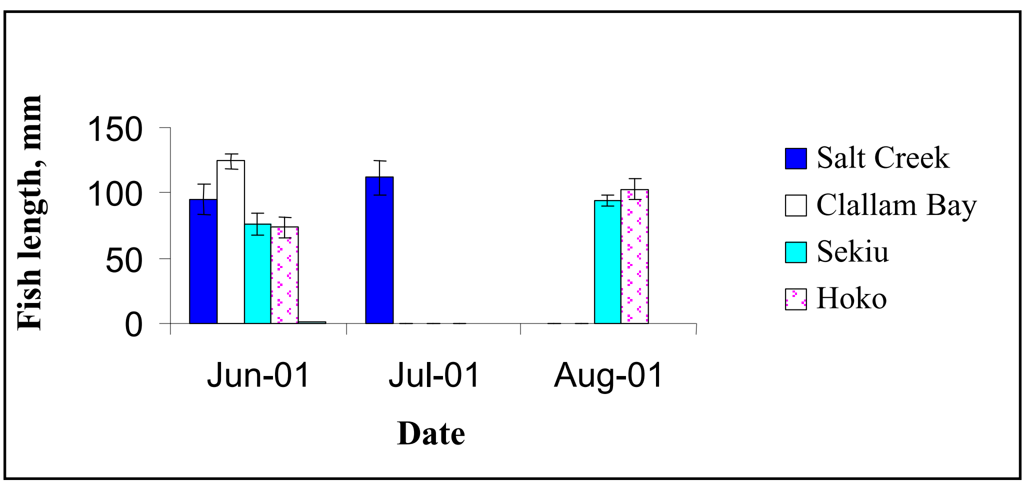

Figure 3. Coho lengths (+/- sd) for the Strait of Juan de Fuca summer 2001

Table 3. Juvenile fish density by site. Log natural densities are per square meter.

Site	Salmon						Sandlance						Surfsmelt					
	all types	se	just kelp	Se	no-kelp	se	all types	se	just kelp	se	no-kelp	Se	all types	se	just kelp	se	no-kelp	se
Sekiu	6.18	0.55	6.46	0.64	5.32	0.00	8.40	0.94	8.66	0.91	7.63	2.30	7.48	1.10	8.20	1.26	5.32	0.00
Hoko	6.15	0.38	6.42	0.42	5.33	0.00	6.48	0.53	6.87	0.59	5.33	0.00	6.90	0.78	7.43	0.88	5.33	0.00
Clallam Bay	5.50	0.48	5.71	0.57	4.86	0.00	7.19	0.83	7.45	0.89	6.40	1.54	6.50	0.53	7.05	0.51	4.86	0.00
Pillar Point	5.88	0.27	6.02	0.32	5.47	0.00	7.71	0.94	7.68	0.93	7.78	2.30	6.61	0.55	6.29	0.56	7.57	1.05
Salt Creek	6.31	0.32	6.70	0.27	5.17	0.00	8.30	1.51	9.34	1.71	5.17	0.00	8.91	0.96	10.16	0.75	5.17	0.00

Table 4. Percent prey composition of juvenile coho collected from monthly beach seines of five streams along the Strait of Juan de Fuca.

Prey composition	sand lance	surf smelt	gammarid amp	crab zoea	diptera	hemiptera	polychaete	tanaid	arachnid	cumacea	mysid	calanoid	bryozoan
By weight	14	0	74	0	5	1	0.19	0	0	0.1	5.7	0	0.1
By number	0.2	0	95	0.7	1	0	0.48	0.17	0.04	0.4	0.8	0.4	0

Discussion

High numbers of forage fish observed in the nearshore in this study are consistent with previous studies (Fresh, 1979; Miller et al. 1980; Simenstad et al 1988). The juvenile salmon and surf smelt preference for vegetated habitats observed in this study is consistent with results found by others. Bell et al. 1987 found that the abundance of juvenile fish was significantly higher in artificial vegetated areas than in bare substrate. Murphy et al. 2000 observed higher densities of chum fry in kelp beds than other vegetation types during June sampling.

The preference for kelp habitat by juvenile surf smelt and salmon, and in particular the middle kelp bed area for juvenile salmon may be due to increased habitat diversity and associated enhanced prey resource availability and refuge from predators. Healey (1982) found that juvenile salmonid migration in the Strait of Juan de Fuca during summer months was driven by foraging success. For other fish species it has been documented that within vegetated habitats, both predator behavior and predation rates change with habitat structure density and species of both prey and predator. For some species, dense habitat is the most efficient for both predator avoidance and feeding. (Savino and Stein 1989). Kelp habitats are documented to have increased secondary production (Duggins et al 1990; 1988) and diversity, including plankton and epiphytic fish prey resource (Gaines and Roughgarten 1987; Shaffer in prep Shaffer et al 1995). In this study, the middle kelp bed area may offer the highest habitat diversity and therefore provide optimal foraging and or refuge. More detailed work should be done to confirm if habitat diversity is the reason for selection of kelp beds, and in the case of juvenile salmon, the middle kelp bed.

Observations of this study indicate that juvenile forage fish use of kelp habitats is complex, and that habitat partitioning may be occurring between juvenile surf smelt and sand lance. Both juvenile surf smelt and sand lance were found in the nearshore in high numbers. While both species are pelagic schooling fish, surf smelt appear to prefer the kelp bed habitat, juvenile sand lance do not. Pelagic schooling fish, including surf smelt and sand lance, are documented to have a) clear habitat preferences for sheltered and more productive nearshore waters (Abookire et al 2000; Fechhelm et al 1999, and b) complex life histories, including seasonally dependant schooling behavior and quickly shifting prey resource bases. These strategies are driven by predator avoidance, prey resource availability and competition for food (Fechhelm et al 1999; Willettee et al. 1996). These elements likely define surf smelt and sand lance use of nearshore habitats including kelp beds. Much more detailed work is needed to clarify the specific role of each for these juvenile forage fish when in kelp habitats.

Trends observed between fish density and distance from shore and creek mouth indicate that salmon of this study preferred shallower water. This is consistent with other work that documented shallow habitat use prior to offshore migration (Roni and Weitcamp 1996; Simenstad et al 1988). Neither salmon nor surf smelt showed any preference for kelp beds closer to creek mouths, indicating no loyalty by juvenile salmon to natal streams once they enter marine nearshore waters. This is supported by five tagged hatchery juvenile Chinook collected in this study, which were collected along shorelines up to two miles away from their natal stream immediately after hatchery release.

Sand lance density however showed a strong negative correlation to distance from creek mouth, indicating that there is an interaction between sand lance use of nearshore and proximity to freshwater streams. More work should be done to confirm and clarify this trend.

Juvenile coho prey composition observed in this study is similar to both prey assemblages observed in earlier work of the Strait of Juan de Fuca and other areas of Puget Sound (Miller et al 1980; Simenstad et al. 1979). Some species of gammarid amphipods, the dominant prey group for juvenile salmon collected in this study, are also dominant in kelp beds (Shaffer in prep, Shaffer et al 1995). Kelp beds have been documented to support complex nearshore food webs (Duggins 1988; Eckman et al. 1989). While juvenile chum salmon are documented to be a part of a detritially based food web (Simenstad et al. 1979), the role of kelp within trophic webs of juvenile Chinook and coho salmon is less known, and intriguing. Further work to define specific trophic habitat linkages between kelp bed habitats and juvenile salmon is warranted, and sorely needed.

Habitat and resource partitioning by juvenile salmon relative to forage fish are also indicated from various elements of this study. In particular:

1. The fact that juvenile surf smelt were not feeding while coho where feeding heavily indicates resource partitioning between juvenile salmon and forage fish may be occurring.
2. The fact that no sand lance were collected in any of the beach seines indicates habitat partitioning between juvenile sand lance and juvenile salmon and surf smelt.
3. Snorkeling surveys indicate that juvenile sand lance are selecting for a different habitat than juvenile surf smelt and salmon.

Willette et al 1996 concluded that habitat choice of forage fish is determined by relative profitability associated with each habitat use. Defining the 'relative profitability' of unvegetated and kelp habitats for each of these juvenile fish groups should be central to future work.

In summary, this study indicates that kelp bed habitats are important for, and preferentially used by, both juvenile salmon and surf smelt. Salmon appear to preferentially select the middle kelp bed areas, possibly due to optimal feeding and refuge conditions this area of the kelp bed may offer. Combined, these results indicate habitat partitioning between these three juvenile fish species. Further quantification of fish use of kelp habitats, including radio tagging of fish, and defining juvenile salmonid and forage fish trophic relationship to kelp habitats, are compelling next steps in defining the relationship between juvenile salmon, forage fish, and their use of nearshore kelp habitats. Such habitat and trophic information is a critical element for the success of future habitat and resource management of nearshore habitat and the salmon and forage fish resources that depend on them (Stephenson 1996).

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References

Abookire A.A., J.F. Piatt and M.D. Robards. 2000 Nearshore fish distribution in an Alaskan estuary in relation to stratification, temperature, and salinity.2000. Estaurine Coastal and Shelf Science 51:45-49.

Bell, J.D., M. Westoby and A.S. Steffe. 1987. Fish larvae settling in seagrass: do they discriminate between beds of different density? J. Exp. Mar. Biol. Ecol. 111:133-144.

Birtwell, I.K and G.M. Kruzynski. 1989. In situ and laboratory studies on the behavior and survival of Pacific salmon (genus Oncorhynchus). In: Environmental Bioassay techniques and their applications pages. Hydrobiologia 188-189: 543-560

Carr, M.H. 1989. Effects of macroalgal assemblages on the recruitment of termperate zone reef fish J.Exp. Mar.Biol.Ecol. 126:59-76

Carter, R. A. 1982. Phytoplankton biomass and production in a southern Benguela kelp bed system. Marine Ecology Progress Series. 8 (1): 9-14.

Ciannelli, L. 1996. Winter dormancy in Pacific sand lance *Ammodytes hexapterus* in relation to gut evacuation time. In: Forage fish in Marine Ecosystems. Lowell Wakefield Fieries Symposia. University of Alaska Sea Grant Program #71. Fairbanks, Alaska.

Duggins, D.O. 1988. The effects of kelp forests on nearshore environments: biomass, detritus, and altered flow. In G.R. VanBlaricom and J.Estes, Eds. The Community Ecology of Sea Otters. Springer-Verlag, Berlin.

Duggins, D.O. C.A. Simenstad and J.A. Estes. 1989. Magnification of secondary production by kelp detritus in coastal marine ecosytems . Science 245 (4914): 170-173.

Duggins, D.O. J.E. Eckman, and A.T. Sewell. 1990. Ecology of understory kelp II: effects of kelps on recruitment of benthic invertebrates. J.Exp.Mar.Bio.Ecol. 143 (1-2): 27-45.

Eckman, J.E., D.O. Duggins, and A.T. Sewell 1989. Ecology of understory kelp environments I: effects of kelps on flow mediation and particle transport near the bottom. J.Exp.Mar. Bio.Ecol. 129 (2): 173-187.

Fechhelm R.G., W.J. Wilson, W.B. Griffiths, T.B. Stables, and D.A. Marino. 1999 . Forage fish assessment in Cook Inlet oil and gas development areas. Environmental studies program Minerals Management Services, Alaska OCS Region, Anchorage Alaska.

Fresh, Kurt L. 1979. Distribution and abundance of fishes occurring in the nearshore surface waters of northern Puget Sound, Washington. Master's Thesis, University of Washington School of Fisheries, Seattle, Washington.

Gaines S. and J. Rougharden 1987. Fish in offshore kelp forests affect recruitment of intertribal barnacles. Science 235 (4787) 479-480.

Healey, M.C. 1982. The distribution and residency of juvenile Pacific salmon in the Strait of Georgia, British Columbia, in relation to foraging success. PROCEEDINGS OF THE NORTH PACIFIC AQUACULTURE SYMPOSIUM. pp. 61-69. Alaska Sea Grant Program, University of Alaska

Holbrook, S.J., M.H. Carr, R.J. Schmitt, and J.A. Coyer, 1990. Effect of giant kelp on local abundance of reef fishes: the importance of ontogenetic resource requirements. Bull.Mar. Sci. 39 (2) 202-212.

Meyer, R. 1996. Forage fish in marine ecosystems: introduction. In: Forage fish in Marine Ecosystems. Lowell Wakefield Fisheries Symposia. University of Alaska Sea Grant Program #71. Fairbanks, Alaska.

Miller, B.S., C.A. Simenstad, J.N. Cross, K.L.Fresh, S. N. Steinfort. 1980. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan de Fuca including food habits of common nearshore fish. Final report of three years sampling 1976-1979., MESA report EPA-600/7-80-027 EPA Seattle, Washington.

Moulton, L.L. and D.E. Penttila 2000 Forage Fish Spawning Distribution in San Juan County and Protocols for Sampling Intertidal and Nearshore Regions. Northwest Straits Commission. Mount Vernon, Wa.

Murhpy, M.L,, S.W. Johnson, and D.J. Csepp. 2000. A comparison of fish assemblages in eelgrass and adjacent subtidal habitats near Craig, Alaska. Alaska Fishery Research Bulletin. 7:11-21.

Penttila D.E 2002. Effects of shading upland vegetation on egg survival for summer spawning surf smelt on upper intertidal beaches in Puget Sound. In Proceedings, Puget Sound Research Conference 2001. Puget Sound Action Team, Olympia, Wa

1995 The WDFW's Puget Sound intertidal baitfish spawning beach survey project. In: Puget Sound Research 95 Conference Proceeding, Vol. 1, Puget Sound Water Quality Authority. Olympia, Wa. pp. 235-241

Puget Sound Water Quality Action Team. 1996. Recommended protocols for measuring selected environmental variables in Puget Sound. Puget Sound Water Quality Action Team, Olympia, Washington.

Robards, M.D, J.F. Piatt, A.B. Kettle, and A.A. Abookire. 1988. Temporal and geographic variation in fish communities of lower Cook Inlet, Alaska. Fisheries Bulletin 97 (4): 962-977.

Roni, P. and L.A. Weitcamp 1996. Environmental monitoring of Manchester naval fuel pier replacement Puget Sound Washington 1991-1994. Coastal Zone and Estuary Studies Division, NMFS, Seattle, Washington.

Savino .J.F. and R.A. Stein 1989. Behavior of fish predators and their prey: Habitat choice between open water and dense vegetation. Environmental biology of fishes. 24(4): 287-293.

Shaffer, J.A. 2000. Seasonal variation in understory kelp bed habitats of the Strait of Juan de Fuca. Journal of Coastal Research 16 (3): 768-775.

Shaffer, J.A., D.C. Doty , R.M. Buckley and J.E. West. 1995. Crustacean community composition and trophic use of the drift vegetation habitat by juvenile splitnose rockfish Sebastes diploproa. Marine Ecology Progress Series. 123:13-21.

Simenstad, C. A., K.L. Fresh, and E.O. Salo 1981. Role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function. Estuaries 4 (3): 285-6.

Simenstad, C. A., R.M. Thom, K.A. Kuzis, J.R. Corrdell, and D.K. Shreffler. 1988. Nearshore community studies of Neah Bay, Wa. Fisheries Research Institute, University of Washington Report number FRI UW-8811, Seattle, Washington.

Simenstad, C.A., B.S. Miller, C.F. Nyblade, K. Thornburgh, and L.J. Bledsoe. 1979. Food web relationships of Northern Puget Sound and the Strait of Juan de Fuca: A synthesis of available knowledge. EPA-600-7-79-259 EPA, Seattle, Washington.

Stepenson, R.L. 1996. The other F: forage consideration in fisheries management. . In: Forage fish in Marine Ecosystems. Lowell Wakefield Fieries Symposia. University of Alaska Sea Grant Program #71. Fairbanks, Alaska.

VanWagenen, R.F. 1996. Washington Coastal Kelp Resources: Port Townsend to the Columbia River. Final report for the Washington Department of Natural Resources, Olympia, Washington. 175 p.

Willette, M. M. Sturdevant, and S. Jewett 1996. Prey resource partitioning among several species of forage fish in Prince William Sound. In: Forage fish in Marine Ecosystems. Lowell Wakefield Fieries Symposia. University of Alaska Sea Grant Program #71. Fairbanks, Alaska.